

## **An update on the TEAM project - first results from the TEAM 0.5 microscope, and its future development**

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Recent advances in aberration-correcting electron optics have led to increased resolution, sensitivity and signal to noise in atomic resolution microscopy. Building on these developments, the TEAM project was designed to optimize the electron microscope around aberration-corrected electron optics and to further advance the limits of the instrument and the technique [1]. The vision for the TEAM project is the idea of providing a sample space for electron scattering experiments in a tunable electron optical environment by removing some of the constraints that have limited electron microscopy until now. The resulting improvements in resolution, the increased space around the sample, and the possibility of exotic electron-optical settings will enable new types of experiments. The TEAM microscope will feature unique corrector elements for spherical and chromatic aberrations, a novel AFM-inspired specimen stage, a high-brightness gun and numerous other innovations that will extend resolution down to the half-Angstrom level.

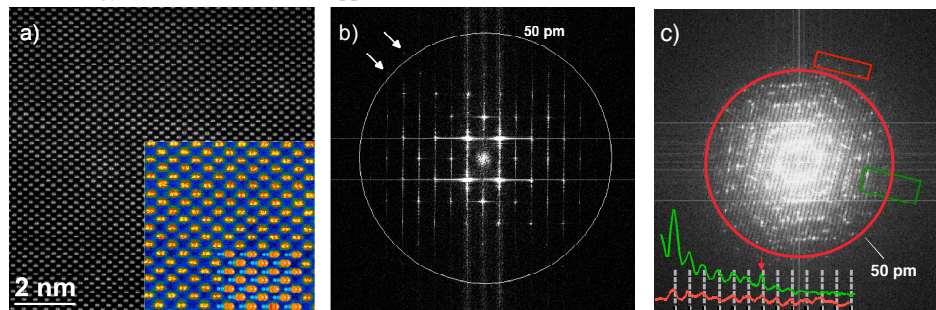
The project is a collaboration of several Department of Energy-funded efforts [1] and two commercial partners (FEI and CEOS). Led by the National Center for Electron Microscopy, the project pursues several key developments in parallel, with each partner responsible for a specific set of tasks. The machine is being implemented in two stages – TEAM 0.5 in 2008 and TEAM I in 2009.

The TEAM 0.5 instrument is a double Cs-corrected microscope with a hexapole aberration corrector on the imaging side that fully corrects aberrations up to third order and partially up to fifth order, and an improved hexapole aberration corrector on the probe side that fully corrects aberrations up to fifth order with an information transfer to 0.05 nm. The machine is equipped with a specially developed high brightness gun and a Wien-type monochromator. Following installation at NCEM in January 2008 and subsequent site acceptance, the instrument is currently undergoing a series of tuning and alignment procedures in preparation for the start of user operations in October 2008.

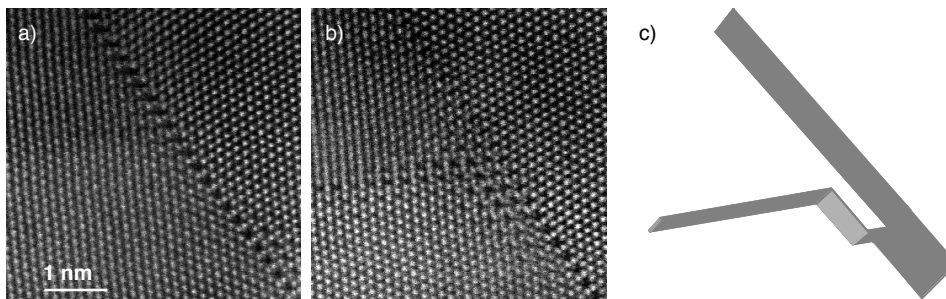
This talk will illustrate initial applications of the TEAM 0.5 instrument to the analysis of different materials. The performance of the instrument [2] in both TEM and STEM operating modes is illustrated in Figure 1. An application of the enhanced depth resolution at large convergence angles in the STEM mode is shown

in Figure 2. Other applications will be demonstrated, including defects in Au, ZnO, GaN, Al-Li based alloys, graphene sheets and grain boundaries in Au bicrystals [3].

1. Lawrence Berkeley National Laboratory, Argonne National Laboratory, Oak Ridge National Laboratory and the FSMRL at the University of Illinois. For more details, see <http://ncem.lbl.gov/TEAM-project/index.html>
2. C. Kisielowski, B. Freitag, M. Bischoff, H. van Lin, S. Lazar, G. Knippels, P. Tiemeijer, M. van der Stam, S. von Harrach, M. Stekelenburg, M. Haider, S. Uhlemann, H. Müller, P. Hartel, B. Kabius, D. Miller, I. Petrov, E. A. Olson, T. Donchev, E.A. Kenik, A. Lupini, J. Bentley, S. Pennycook, I.M. Anderson, A.M. Minor, A.K. Schmid, T. Duden, V. Radmilovic, Q. Ramasse, M. Watanabe, R. Erni, E.A. Stach, P. Denes, U. Dahmen, submitted for publication. See also other presentations at this meeting.
3. The TEAM project is supported by the Department of Energy, Office of Science, Basic Energy Sciences. NCEM is supported under Contract # DE-AC02-05CH11231.



**Figure 1.** Performance of TEAM 0.5 microscope in STEM and TEM. Aberration-corrected high-resolution STEM image of GaN in [211] orientation (a), showing the 0.63 Å distance between Ga dumbbells clearly resolved (see inset model). The corresponding diffractogram in (b) shows Fourier components beyond the 50 pm marker indicated by the circle. The Fourier diffractogram from high resolution TEM images in (c) shows Young's fringes extending beyond the 50 pm mark indicated by the circle.



**Figure 2.** HAADF STEM images of a faceted grain boundary in a Au bicrystal viewed along the [111] direction (a). A buried boundary segment becomes visible only when the probe is focused 7 nm into the sample (b). A schematic of this geometry is shown in (c). 300 kV, probe semi-convergence angle: 35.6 mrad, inner detector angle ~50 mrad.